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STRATEGY PAPER

THE FUTURE OF COAL, CLEAN COAL TECHNOLOGIES AND CCS IN THE EU AND CENTRAL EAST EUROPEAN COUNTRIES:

STRATEGIC CHALLENGES AND PERSPECTIVES

Dr. Frank Umbach

In cooperation with

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1. FOREWORD / PREFACE

Dr. phil. Friedbert Pflüger Professor and Director of the European Centre for Energy and Resource Security (EUCERS) at the Department of War Studies, King's College London.

The study "The Future of Coal: Clean Coal Technologies and Carbon Capture and Storage (CCS)" addresses the global and European dimensions of CCS - the opportunities but also the challenges associated with this new technology that may spark a revolution in our future energy policies.

Its starting-point is the realization that coal is not an outdated, disappearing source of energy. Quite contrary to the predominant perception in Europe, coal is in fact the second-most important source of energy after oil globally, largely due to high consumption rates in emerging countries. And coal is still on the rise – the International Energy Agency projects a further increase in coal use and states in its World Energy Outlook 2011 that, with no change in policies, coal consumption could even overtake oil by 2035. Since coal is here to stay, at least over the medium-term, it is necessary to point out that it should not be demonized as an energy source. Instead, new and innovative solutions are needed to maximize its energy potential while keeping environmental costs to a minimum. We shall have to live with oil, coal, and gas for a long time; therefore it is necessary to work for the "greening of fossil fuels".

Given the twin challenges of achieving long-term energy security, on the one hand, and mitigating the effects of climate change, on the other, this study highlights the potential for coal in conjunction with CCS technologies to actually help address both simultaneously.

Currently, CCS is the only technology that can capture at least 90% of the emissions from the world's largest CO2 emitters. The study investigates the countless opportunities for the application of CCS, even beyond coal-based industries. In the long term, for example, even stored CO2 may possess economic value, rather than just being a waste product. Given these fascinating developments and the challenges ahead, the study implores us to rethink our approach to energy in the 21st century.

Instead of a strict dichotomy, coal (but also other conventional energy sources) in conjunction with CCS and renewables may actually be best seen as complementing each other. Yet there are many tasks still ahead for European policy-makers before CCS can be a vital component of our energy systems, not only in Poland, Hungary, the Czech Republic and Slovakia, which are the empirical focus of this research.

One of the primary challenges that needs to be addressed before the large-scale development and widespread application of CCS technology is realistic, is to prove its competitiveness and commercial viability. It cannot be denied that technological change always involves significant costs, which is why coal-based energy with CSS will be more expensive than its counterpart without it. But there are several reasons for being cautiously optimistic.

First, there is a growing awareness that outsourcing emissions does not equal an actual reduction; if the carbon content of imported energy sources and products is included in, for example, Europe's balance-sheet, the relative cost of developing and implementing new, domestic technologies goes down. Second, CCS is not only needed in coal-based industries, but in many others, including gas and oil, which will also involve considerable start-up costs. Third, stored CO2 should not be looked at as a waste product; many applications are currently being developed through which CO2 can have economic value, for example in Enhanced Oil and Gas Recovery or for storing electricity from renewable energy sources in gas pipeline networks ("Power-to-Gas" projects). Finally, the development of CCS technology means that there will be a huge export potential for European power plant manufactures and operators as well as industrial technology companies that will create hundreds of thousands of jobs in Europe. All in all, despite the enormous costs, CCS holds such a huge potential that the initial challenges, at least, do not seem insurmountable.

I would like to take the opportunity to thank our Associate Director of the European Centre for Energy and Resource Security (EUCERS) Frank Umbach for his very important and insightful study, on which this strategy paper is based and which will be published in book format at a later point. I also thank Prof. Mervyn Frost and King's College London for supporting our work at EUCERS. A special thank you goes to the Central Europe Energy Partners (CEEP), an international nonprofit association based in Brussels, for their great co-operation throughout the project; CEEP's knowledge and experience remains of great importance to EUCERS work also in the future. Moreover, I would also like to thank Grupa LOTOS S.A. for funding this research study. Many thanks also go to the participants of the roundtable discussion on CCS, which was organized by EUCERS on September 1, 2011 at King's College London together with the Atlantic Council of the US to discuss the first results of the study and new approaches towards the capturing, storage and usage of carbon dioxide. Last, but not least, I would also like to thank Arash Duero for helping to edit this Strategy Paper.

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2. INTRODUCTION: A WORLD WITHOUT COAL - 2.1 THE GLOBAL FUTURE OF COAL

2.1 The Global Future of Coal

"Depending on fuel and carbon prices, coal has an excellent long-term perspective and an excellent competitive position in power generation in the European Union. Especially at high fuel price assumptions, coal is on the way to push back power options. Even at moderate prices, solid fuels remain competitive at carbon prices of 15€/t."[1]

Contrary to the widespread perception by the European public, coal is still the world's second-most important energy resource (after oil) in terms of energy consumption. European-centric views are corroborated by the fact that European hard coal production has declined over the past 30 years, in contrast to global energy trends. But the abundance of recoverable coal reserves spread across the globe means that coal is projected to be available for a significantly longer period than conventional oil and gas resources. In contrast to oil and gas, most of which are produced outside of Europe in often politically unstable parts of the world, coal (of which significant amounts are produced in high-demand regions) is seen as a secure and affordable supply source that is not subject to the risk of major interruptions and the resulting price as well as supply risks. And unlike oil and gas, coal has never been considered a strategic resource.[2]

The recent revolutions in North Africa, the unrest in Bahrain and the ensuing military intervention by Saudi Arabia, as well as civil wars in Yemen and Libya, have underscored the importance of domestic energy resources for Europe's future energy security. Widespread political instability and violent internal conflicts have led to supply disruptions of oil and gas to Europe and other parts of the world. In the EU, and in particular in Italy and Spain, the uprisings in the Arab world have highlighted the challenge of energy supply security, its sensitivity to political instability in oil- and gas-producing states in the Middle East and the geo-economic as well as geopolitical importance of the *"Strategic Ellipse"* (Persian Gulf and the Caspian region), where over 70% of the world's remaining conventional oil and more than 40% of the world's remaining conventional gas resources are concentrated. While Italy, Spain and the rest of the EU were able to compensate for the disruption of gas supplies from Algeria (as the EU's third largest import source) and Libya by importing more *Liquefied Natural Gas (LNG)* from other countries and regions, Italy's energy stability could become much more severely affected by a supply disruption in the winter months around 86-114 days after the start of a cut-off, depending on the actual demand, as Lochner and Dieckhöner were able to demonstrate in a scenario-based analysis.[3]

Understandably, Russia has used the opportunity to present itself as a haven of political stability, with its oil and gas supplies to Europe on which the EU can rely for its future energy security. Quite contrary to its self-portrayal, Russia - Europe's most important energy partner – has, as the result of the Russian-Ukrainian energy crises in 2006 and in 2009 showed, prompted the most serious energy crisis in Europe since the oil crisis in the 1970s. Because of this, it is perceived as an unreliable and assertive partner who uses the asymmetric interdependence with the EU-27 and its energy dependence on *Gazprom* as a foreign policy instrument to extend its geopolitical influence across the Eurasian landmass. Since the first Russian-Ukrainian gas crisis in January 2006, the EU's dependence on the import of natural gas has widely been seen as the *"Achilles heel"* of Europe's energy security. The growing concerns about the EU's gas supply security

[1] **Prognos AG**, The Future of Coal in Europe – Final Report, Basel-Berlin 2007, p. 13.

[2] **See Euracoal**, An Energy Strategy for Europe. Importance and Best Use of Indigenous Coal, Brussels 2009 and idem, Guaranteeing Energy for Europe – How Can Coal Contribute?, ibid., and Sandro Schmidt/Sönke Rehder/Benhard Cramer, Quo vadis Kohle?, Commodity Top News, No. 32, BGR, Hannover 13 November 2009.

[3] **See Stefan Lochner/Caroline Dieck Dieckhöner**, Civil Unrest in North Africa: A Risk for Europe's Natural Gas Supply? – A Scenario-Based Analysis, Energiewirtschaftliches Institut an der Universität Köln (EWI), Cologne 2011 und dies., Civil Unrest in North Africa – Risks for Natural Gas Supply?, EWI-Working Paper, No. 11/01, ibid., April 2011

are the result of a combination of trends, such as an increasing reliance on natural gas in its energy mix for environmental reasons, the ongoing depletion of its own gas resources in the North Sea, an increasing dependency on Russia and its only gas export company *(Gazprom)*, and its heavy dependency on an inflexible pipeline system, which in a major crisis is a far greater liability compared to oil and LNG ships, which could be rerouted to other gas fields and countries in case of a technical or political supply cut off. Those concerns are even more relevant in light of the rising global demand for natural gas.

For these reasons, a continued sustainable supply of coal as a domestic resource, equipped with clean coal technologies, needs to be reconsidered. The manifold uses of coal were critically important for the economic development and poverty alleviation in many countries around the world. Without affordable coal, electrification – and, along with it, modernization and education - in countries like South Africa, India and China would have been impossible. Coal has remained critical for electricity generation, steel and aluminum production, and cement manufacturing; in addition, it is also being used as a liquid fuel. Presently, 75 countries possess proven coal reserves, and coal can been mined in more than 50 countries. Hard coal, together with lignite, accounts for no less than about 55% of all fossil energy resources.

Between 1999 and 2009, worldwide total coal production increased by 54% (hard coal +66%).[4] **Since 2000, global coal consumption has grown annually by 4.4% - faster than any other fuel. In 2010, even OECD-coal consumption rose by 5.2%, the biggest increase in 31 years; that year, coal also accounted for the largest increase among all the fossil fuels.**[5] During the last 20 years, steam coal trade by sea has increased annually by 7% and coking coal trade by sea by another 1.6%, amounting to a total of 938 million tons (mt) in 2008.[6] With a proportion of 27% of the global primary energy mix, coal is used primarily for power generation in power plants in the base and medium-load range. For global power generation, coal is still the most important energy resource with a share of 41% in 2008. In the mid-term, however, this share will decline to around 32% by 2035, according to a projection by the *International Energy Agency (IEA)* in its *"New Policy Scenario"*; but the use of coal in volumes may rise up to 65%, depending on the three energy scenarios in the latest *"World Energy Outlook"* report of 2011.[7]

But despite the fact that coal causes the highest CO2 emissions of all fossil fuels, almost all international energy organizations and experts assume that it will continue to play a major role in the world energy supply – at least through 2035. But even in the longer perspective until 2050, it does not appear realistic to expect a world without coal. Furthermore, most public energy debates overlook that new coal production and coal transformation options for liquefying or gasifying coal are underway for the development of commercial operation. Another "silent revolution" - like the development of unconventional gas resources in the U.S. and the associated new drilling technologies – of *"King Coal"* cannot be excluded (i.e., underground coal gasification/UCG) in the years to come.

In addition, for Europe another strategic development has been overlooked for years: The European and EU market share is continuously declining alongside a power shift toward the new consumer centers in the Asia-Pacific (China, India and others), which will restructure the overall international trade patterns and structures of the international coal markets. Presently, European coal prices are already increasingly

4 **See IEA**, Coal Information 2010 (with 2009 data), Paris 2010, p. II3.

5 **See also Euracoal**, Coal Industry across Europe 2011, Brussels 2011.

6 The **"New Policy Scenario" (NPS)** can be seen between the traditional "Reference Scenario ("Business-as-usual") and the most ambitious 450 Scenario closely linked to the Kyoto-Climate Protection policies and the agreed 2°C-target. The NPS considers the full implementation of already announced, but yet not (fully) implemented energy policies and their objectives up to now - see International Energy Agency (IEA), World Energy Outlook (WEO) 2011, Paris 2011, pp. 353 ff. and World Energy Council (WEC), 2010 Survey of Energy Resources, London 2010, Chapter 2: coal.Global Oil & Gas Study. NPC

7 **See ibid**.

affected by the rising coal demand in China and India.[8] Furthermore, China itself - together with Australia (the world's largest exporter of hard coal) - has become a leader in the promotion of clean coal technologies, and is supporting new technology options such as ***Carbon Capture and Storage (CCS), Coal-to-Liquids (CTL), Coal-bed Methane (CBM) and Underground Coal Gasification (UCG).***

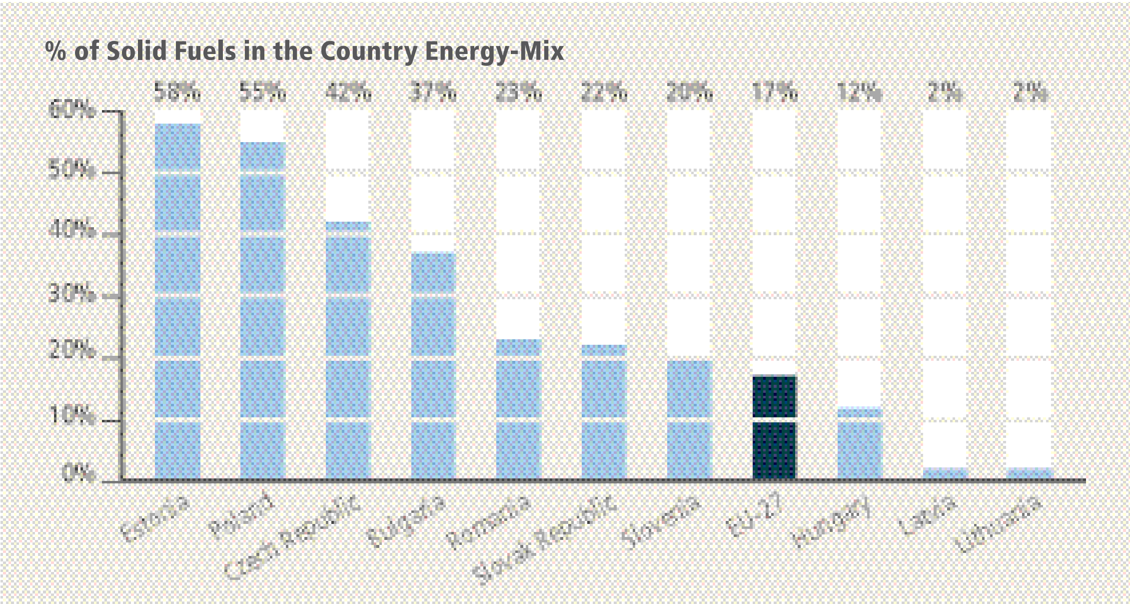
In 2009, the EU Heads of Government committed themselves to reducing Europe's Greenhouse Gas Emissions (GHGE) by 80% to 95% from 1990 levels by the year 2050. The EU and major industry favor a **de-carbonisation policy that consists of a three-way strategy:**

- Fuel-switching, away from coal and oil to gas and renewables (RES);
- Energy saving (e.g., reducing transmission losses and insulating buildings);
- Deployment of new clean-coal technologies (CCS, smart grid, new chlorine processes, etc.).

Given that Central European countries, namely Poland, the Czech Republic, Hungary and Slovakia, in fact do not have genuine national energy markets by themselves, due to their small size, and are therefore unable to achieve a sustainable form of energy security, the challenges for the future of coal, and in particular concerning the introduction of clean technologies including *CCS* projects in these countries, cannot be dealt with exclusively or primarily at the national level.

Instead, it is necessary to consider stronger cooperation on a regional (EU-10[9]) or sub-regional (Central East Europe) level when it comes to utilizing available and new emerging technologies, along with joint strategies

TABLE 1: SOLID FUELS SHARE (IN %) IN THE ENERGY MIXES OF EU-10 COUNTRIES



Source: CEEP and data sources for 2008 year: EC (ESTAT, ECFIN), EEA, Market Observatory for Energy.

8 **See also Federal Institute for Geosciences and Natural Resources (BGR)**, Annual Report 2010 - Reserves, Resources, Availability, Hannover 2011, p. 30.

9 **See Ernst & Young, Central Europe Energy Partners**. Proposition for the EU-10 Countries, 2011. The EU-10 countries are Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

for expensive projects.[10] On average, coal-fired energy accounts for 30% of the total power generation capacity in the four Central East European states. In Poland and most of the other EU-10 countries, the very high dependence on Russian oil, gas and electricity imports as well as the currently significant role coal plays in the energy mix, in particular for electricity generation (accounting for more than 90% of total electricity generation), are important arguments in favor of a continued future role of coal as a domestic, affordable and rather inexpensive fossil energy source in the energy mix as well as energy security strategy. But coal's high CO2 emissions need to be decreased significantly in the future by enhancing the energy efficiency of existing coal-fired plants and by introducing CCS as well as other clean coal technologies.

2.2 CCS as a Future Key Technology for the Energy Sector and Energy-Intensive Industries

Given that coal is both abundant and relatively cheap, it will continue to play a significant, albeit a declining role in European power generation; outside of the EU-27, particularly in the BRIC-states (i.e. China, India et.al) and other emerging economies, it will play an even larger role – despite a rapid expansion of renewable energies. Due to the need to mitigate global climate change, carbon dioxide management will become increasingly important. The only available and critically enabling technologies today that address these challenges are **various technology options to increase the efficiency of power plants and CCS to help significantly reduce CO2 emissions.** It will allow coal to contribute to the diversification of national and global energy and, thus, to guarantee global energy security in the wake of rising demand and declining fossil fuels. CCS is presently the only technology that can capture at least 90% of the emissions from the world's largest CO2 emitters; it combines the advantages of allowing continued the use of domestic resources while being relatively more advanced than many other alternative technologies under development. Thus, the widespread deployment of advanced coal technologies in the energy sector and energy-intensive industries could not only increase their efficiency, but could simultaneously reduce the demand for coal and increase the worldwide use of coal because of the breakthroughs in CCS technologies.[11]

Fossil fuel power plants and heavy industries are the largest emitters of CO2, accounting for 52% of total CO2 emissions worldwide – totaling around 15 billion tons (bt) of CO2 annually. A single 1,000 Megawatt (MW) produces 6 million tons (mt) of CO2 per year. Based on these numbers, the IEA and the *European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP) assume* that **the world needs to build 3,400 commercial projects worldwide by 2050 if CCS is to provide 20% of the global CO2 reductions required for limiting the impact of climate change to a temperature rise of 2°Celsius.**[12] According to the IEA and its 450 Scenario, which adopts the *Copenhagen Accord's* goal to mitigate climate change to a warming of the global climate by not more than 2°C, the rapid transformation of worldwide energy policies also needs to include both the expansion of nuclear power (also in OECD countries) as well as the use of CCS to reduce power sector emissions. The scenario expects that by 2035 power generation by coal plants fitted with CCS will exceed that of coal plants without CCS.

At present, modern coal plants reach an efficiency level of up to 45% (the worldwide average is around 30%) and thus contribute to the reduction of CO2 as part of worldwide efforts to mitigate climate change. Regardless of CCS, new and more efficient clean coal technologies in the field of surface and subsurface gasification (Coal-bed Methane/CBM and Underground

[10] **See F.D.Kramer/J.R.Lyman/M.C.Carstei**, Central Europe and the Geopolitics of Energy, Issue Brief, Atlantic Council, December 2010 and Keith Smith, Bringing Energy Security to East Central Europe: Regional Cooperation is the Key, Journal of Energy Security, 29 September 2010.

[11] **See IEA**, WEO 2011, p. 379.

[12] **See IEA**, WEO 2010, p. 54.

Gasification/UCG) and the liquefaction of coal (Coal-to-Liquids/CTL) open up new prospects for the future of *"King Coal"* as one of the primary energy sources. But also **new coal options, such as CBM, CTL and UCG, need to include CCS for the reduction of CO2.** Therefore, future electricity generation from coal conversion/combustion with CCS will never be as cheap as coal plants without CCS. But in contrast to the widespread perception of the European public and the political elite, CCS is not just considered by experts as the only available technology to significantly decrease CO2 emissions in the processes of coal exploration and production. **It is also seen as the only realistic alternative for other fossil fuel resources and energy-intensive industries** to meet the long-term goal of reducing GHG-emissions by 2050, including:

a) Conventional oil and gas industry: Looking beyond 2030 toward the long-term perspective of 2050, the EU's intention to decrease its CO2 emissions by 80% to 95% from 1990 levels appears unrealistic, assuming only traditional drilling and production technologies are used, without applying any CCS technologies.[13] Even in the IEA's newest "Golden Age" scenario that assumes a higher share of natural gas in the global energy mix in comparison with its latest three forecast scenarios, the organization warns: "An increased share of natural gas in the global energy mix is far from enough on its own to put us on a carbon emissions path consistent with an average global temperature rise of no more than 2° C." Instead, even in this Golden Age scenario, the average global temperature rise will hit 3.5°C by 2035.

b) Unconventional oil production: Although a clarification of the legal framework for CCS still needs to be implemented, the IEA expects in all of its three scenarios an expansion of unconventional oil production by 2035 that will meet around 10% of the entire world oil demand due to the limited availability of conventional oil reserves after around 40 years of current production levels. This unconventional oil production will include Canadian oil sands, Venezuelan extra-heavy oil resources, coal-to-liquids (CTL), gas-to-liquids (GTL), coal-and-biomass-to-liquids (CBTL) and oil shales (to a lesser extent). They will make a growing contribution, in particular the second half (beyond 2020) through 2035. Given that the production of unconventional oil is more expensive and generally emits more GHG per barrel than most types of conventional oil (Canadian oil sands' CO2 emissions are 5-15% higher), CCS needs to be included in all these production processes of unconventional gas resources beyond 2030.

c) Energy intensive industries such as paper, chemicals, cement, steel, etc.: In contrast to the energy sector with the additional option of energy efficiency-increasing technologies, CCS is currently the only available means of achieving significant cuts in emissions in these energy-intensive industries.[14] The IEA predicts that, by 2050, 50% of all CCS projects will be applied in the industrial manufacturing sector.[15]

The inclusion of CCS in these future conventional oil and gas explorations as well as in the industrial processes of energy-intensive industries will increase their production costs. As a consequence, after 2030 coal could once again become more competitive vis-a-vis natural gas, although it will not be the cheapest option, based on current estimates.

Yet the introduction of CCS on a significant scale on national, EU- and global levels *"will require the construction and operation of a large infrastructure of pipelines, surface injection facilities and monitoring and analysis network,"* as an interdisciplinary MIT-study on the future of coal already concluded in

13 **See also Floris van Foreest**, Does Natural Gas Need a Decarbonisation Strategy? The Cases of the Netherlands and the UK, The Oxford Institute for Energy Studies, NG 51, May 2011.

14 **See also to the background Karel Beckman**, 'EU Climate Policies are Driving Smelters out of Europe, European Energy Review, 6 June 2011.

15 **Sonya van Renssen**, CCS in Europe under Serious Threat, ibid., 17 November 2011

2007. It also needs a **regulatory framework** that includes certification, the closure of sites, and an appropriate transfer of liability to the government for a safe CO2 transportation and storage system as well as an enforcement and inspection regime to support regulation. Moreover, given the already existing mistrust and local opposition to new coal and CCS-projects in individual EU-member states (i.e., Germany), a **politically acceptable federal assistance package is needed.**[16] **Thus, despite the technological progress, four main challenges lie ahead:**

- Reducing the cost of CCS projects to secure the competitiveness of future fossil fuel plants and energy-intensive industries and to encourage public acceptance as a precondition for a social consensus;
- Developing detailed legal and regulatory frameworks for CCS worldwide;
- Creating financial mechanisms for both developed and developing countries;
- Securing public understanding, acceptance and support.[17]

These four main challenges are interrelated, but do not have equal relevance for individual countries, including the EU-27. Meanwhile, however, these four challenges for large-scale CCS demonstration projects and the future commercialization and operation of integrated CCS technologies in the power and heat sector have not only generated EU-wide cooperation on clean coal technologies (incl. CCS), but also international collaboration, for example in transatlantic relations and in the bilateral US and EU relations with China, respectively.[18]

This study will analyze both the future of coal in Europe as well as the prospects for introducing and applying CCS in the EU-27, with a regional focus on the four *Central East European (CEE)* countries: The Czech Republic, Slovakia, Hungary and in particular Poland. The research approach follows a comprehensive understanding of energy policies and energy security, called *"networked energy security"* (applied from the *"networked security policy"* approach). It will put the focus on the coal and CCS policies of the four CEE-states in a wider strategic context of global megatrends of energy supply security (demand and supply, geopolitical risks and global climate mitigation policies), as well as of the EU's common integrated energy and climate policies. It will not only address the CCS-issue in the short term (till 2020), but also in a strategic long-term perspective (2035/2050).

Within this wider framework, this study contains four major parts: *Chapter II* (following the introduction chapter) will begin by addressing the global dimensions and identifying the global energy megatrends (focusing on coal) along with the worldwide perspectives of CCS and the implications for EU energy policies; *chapter III* will provide an overview of the EU energy policies in general, and its coal policies and the CCS projects in particular; *chapter IV* will address major challenges and the perspectives of CCS in the EU-27; finally, *chapter V* will analyze the energy, coal and CCS policies of Poland, Hungary, the Czech Republic and Slovakia in greater detail.

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16 **See Massachusetts Institute of Technology (MIT),** The Future of Coal. Options for a Carbon-Constrained World. An Interdisciplinary Study, Cambridge MA 2007.

17 **See also Barbara McKee,** The Outlook for Carbon Capture and Storage, in: WEC, World Energy Insight 2010, p. 41 and Eric Hymann, CCS for Climate Protection – Important, Tedious and Costly, Deutsche Bank Research, Frankfurt/M., 4 July 2011.

18 **See Atlantic Council,** U.S.-EU Energy Cooperation on Carbon Capture and Storage Technologies. Energy and Climate Change Solutions, Washington D.C., June 2010; idem, U.S.-China Cooperation on Low-Emissions Coal Technologies, Realities and Opportunities. A Report on a Dialogue sponsored by the Atlantic Council and the U.S./China Energy and Environment Technology Center at Tshingua and Tulane Universities, Washington D.C. 2009 and Frank Umbach, The EU-China Energy Relations and Geopolitics: The Challenges for Cooperation, in: M.Amineh/Y.Guang (Eds.), The Globalization of Energy. China and the European Union' (Koninklijke Brill NV: Leiden-Boston 2010), pp. 31-69.

3. SUMMARY, PERSPECTIVES AND RECOMMENDATIONS

3. Summary, Perspectives and Recommendations - Long Version

The *EUCERS*-study ***"The Future of Coal, Clean Coal Technologies and CCS in the EU and Central East European Countries: Strategic Challenges and Perspectives"*** analyzes the energy policies, and in particular those in the fields of coal and CCS, of the four *Central Eastern European countries (CEE) Poland, Hungary, the Czech Republic and Slovakia* against the background of rapidly changing global and European energy markets as well as worldwide technological innovation. Accordingly, this study contains four major parts: *chapter II* (after the introduction chapter) will begin by addressing the global dimensions and identifying the global energy megatrends (with the focus on coal), the worldwide perspectives of CCS and the implications for EU energy policies; *chapter III* will give an overview of EU energy policies in general, and its coal policies and the CCS projects in particular; *chapter IV* will address major challenges and the perspectives of CCS in the EU-27; finally, *chapter V* will examine the energy, coal and CCS policies of Poland, Hungary, the Czech Republic and Slovakia in greater detail.

On the basis of this comprehensive analysis of global and European energy policies, the role of coal, and the perspectives of CCS and other clean coal technologies, the following **eight major recommendations and strategic perspectives** are being presented, followed by a more detailed summary:

Major Results and Recommendations

1. Recognizing Global and European Energy Realities: Coal is not only the second-most important energy resource in terms of global energy consumption; it has also grown faster than any other fuel during the last 10 years. It is primarily used for power generation in the base and medium-load range. Although the coal share of the world's power generation is projected to decline from presently almost 41% (2010) to around 32% in 2035 *(New Policy Scenario of the IEA)*, the use of coal volumes may rise up to 65%. Taking into account that new coal transformation options, such as coal gasification *(coal-bed methane/CBM and underground coal gasification/UCG)* and *coal-to-liquids (CTL)*, will become much more attractive and are likely to expand throughout the world, there will be no world without coal in the mid-term (i.e., by 2035), and probably not even until 2050, given its worldwide abundance and its relatively low cost compared to oil and gas production. While the 16%-share of coal in the EU's primary energy demand and a share of power generation of 27% are already lower than respective global counterparts, the EU-27 is the world's largest producer of lignite (brown coal) with more than 41%, while at the same time being the largest importer of coal globally. Although the EU's coal consumption is expected to decline more rapidly than in the rest of the world by 2035, coal will - primarily as *an indigenous energy source* – still play an important role in both primary energy demand as well as in power generation, and, consequently, also for the common energy security of the EU-27, including the four CEE countries.

However, the conventional use of coal emits more CO2 emissions worldwide than any other fossil fuel. Given the efforts to mitigate climate change and the EU's ambitious climate protection targets to reduce *Greenhouse Gas emissions (GHGE)*, and in particular CO2, the future of coal is dependent on the introduction of clean coal technologies to enhance the efficiency of coal-fired power plants beyond 50% (the present average is around 30%) in the next decade and *Carbon Capture and Storage (CCS)*-technologies after 2020.

2. Maintaining the Balance within the EU's Energy Triangle and between Its Three Objectives as well as Including Outsourced Greenhouse Gas Emissions into its Environmental and Energy Policies: Hitherto, EU energy policies have primarily not been determined by the goal of achieving a balance within the energy triangle, consisting of energy supply security, environmental protection/climate mitigation and economic competitiveness, but rather by just one factor (environmental protection/climate mitigation) at the expense of the other two. Minimizing the cost of de-carbonization and finding timely solutions will become an ever more important task for the future, which should be tackled by implementing more advanced coal technologies, such as ultra-supercritical plants, IGCC and UCG technologies, to reduce the CO_2 footprint.

Furthermore, the European Commission and the EU-27 member states have focused in their environmental and energy policies almost exclusively on GHGEs produced domestically, but not on outsourced emissions through the inclusion of scientific *"life-cycle"* and *"wells-to-wheels"*-approaches for the rising energy imports from outside Europe. As those recent studies have shown, by including the carbon content of imported energy sources and products, the EU's carbon footprint may have increased 47% since 1990, instead of the officially declared 3% reduction since that time.

3. Considering the Long-Term Strategic Importance of CCS as Part of the Worldwide Climate Mitigation Efforts: Contrary to widespread belief and the view held by many politicians, CCS technologies are not just needed for future coal-fired power plants, but also for new coal transformation options (CBM, UCG, CTL etc.) *as well as for oil, gas and other energy-intensive industries.* CCS is presently the only technology that can capture at least 90% of the emissions from the world's largest CO_2 emitters; it combines the advantages of allowing continued use of domestic resources while being relatively more advanced than many other alternative technologies under development. While the technology's ability to capture and store CO_2 has already been proven, its risks and benefits still need to be tested in large-scale demonstration projects, which will come online in 2015. Without CCS for the use of coal as well as for oil, gas and energy-intensive industries to reduce CO_2 by 20%, the world will not be able to decrease the CO_2 emissions required to succeed in climate mitigation efforts aimed at preventing a global temperature rise of more than 2° Celsius. Hence CCS is an important strategic element of the EU's *"Energy Strategy 2020"*, its long-term vision for 2050 and an enabling key technology for its de-carbonization policy consisting of a *three-way strategy*:

(a) Fuel-switching (away from coal and oil to gas and renewables);
(b) energy saving (e.g. reducing transmission losses and insulating buildings); and
(c) deployment of new clean-coal technologies (CCS, smart grids, new chlorine processes, etc.).

4. Addressing the Four Main Challenges of CCS Implementation: Despite the technological progress, *four main challenges* need to be addressed by the EU-27 and the four CEE countries:

(a) Reducing the cost of CCS projects;
(b) developing detailed legal and regulatory frameworks for CCS worldwide;
(c) creating financial mechanisms for both developed and developing countries; and
(d) securing public understanding, acceptance and support.

5. High-Level Political Support for a Comprehensive, Coherent and Pro-active Public Acceptance Strategy: As two new groundbreaking studies conclude, with the right policy framework, neither the technology nor the costs are themselves the main obstacles to CCS deployment. The real reason for the slowing-down of CCS deployment in Europe is the lack of high-level political support (as a consequence of a failing strategic vision) and public acceptance as a combination of environmental concerns (possibility of contaminating water and suffocation if large quantities of CO_2 should leak out), fears that CCS is a pretext for a continued use of coal in energy consumption at the expense of the rapid expansion of renewables, and NIMBY-attitudes on a local level. While environmental concerns need to seriously be taken into account by the EU and the four CEE governments, a pro-active engagement policy, based on transparency, credibility and information, should also include a five-step strategy encompassing:

(1) A strong political message and support;
(2) support from key society groups;
(3) clear, timely and adequate communication and information;
(4) public engagement before decisions are taken; and
(5) providing local compensation for any inconveniences or damage caused.

6. Supporting and Intensifying Research on Carbon Capture and Use (CCU): While the present focus of international CCS-projects and cooperation is to store CCS permanently underground in geological formations and treat it as a waste product, it should in fact be recognized as an industrial good that can be utilized. This would reduce the burdensome costs of the de-carbonization effort, decrease the storage volumes and allow the use of the storage sites not as a final deposit, but rather as an interim storage facility for the further industrial use of CO2. It could even turn the costs of storage into a revenue flow to support the CCS project's economics. It can be used, for instance, for Enhanced Oil and Gas Recovery *(EOR/EGR)*, including unconventional gas fracturing, but also for fertilizer and synthetic material production, algae-based fuels and storing electricity from renewable energy sources in gas pipeline networks ("Power-to-Gas" projects).

7. Recognizing the Huge Export Potential of CCS in Combination with State-of-the-Art, Highly Efficient Coal and Gas-Fired Power Plants (Given the worldwide interest in and the need for modernizing the power sector and guaranteeing a basic level of electricity supply): At present, European mining technologies are still dominating the world market with a share of more than 50%. Together with most efficient coal-fired plants generating electricity, in combination with CCS, they offer a huge export potential for European power plant manufacturers and operators as well as industrial technology companies that create hundreds of thousands of jobs in Europe, and will contribute significantly to global climate protection policies. Given the long-term need for building 3,400 commercial CCS projects worldwide by 2050, if CCS is to provide 20% of the CO2 reductions necessary for lowering the expected climate change down to 2°Celsius, and 234 active or planned CCS projects worldwide by the end of 2010, other countries such as Australia, China, Norway, Canada and the United States have already recognized not just the importance of CCS for their active climate mitigation efforts, but also its future economic value as a key technology for their energy security and heavy industries. They already have or will take over the EU's hitherto technological leadership in CCS and other state-of-the-art clean-coal technologies.

8. Intensifying Geological Research into Potential Storage Sites and Supporting Subregional Cooperation between the four CEE Countries: Further and intensified geological research into potential storage sites is an urgent need for the CEE countries. Otherwise they will be confronted with the need to build a much more extensive and expensive infrastructure network. But the need for cross-border transports of CO2 is also an excellent opportunity for sub-regional and regional cooperation. They should further consider the option of a *regional CO2 hub* (i.e., between Poland and Slovakia). Given their small size, none of these countries have genuine national energy markets, which leaves them unable to achieve a sustainable energy security on their own,. The challenges for the future of coal, and in particular those involving the introduction of clean technologies, including CCS projects, cannot be dealt with effectively just or primarily through national policies.

These eight major recommendations are made in light of the results of the following detailed summary of this study, which begins with the global dimensions of the future of coal and CCS.

3.1 Global Role of Coal

1. Contrary to the widespread perception by the European public, coal is still the second-most important energy resource after oil for global energy consumption. European-centric views are corroborated by the fact that European hard coal production declined over the past 30 years, in contrast to global energy trends. But it is not only abundant, but it will also be available for a longer time than conventional oil and gas resources. In contrast to oil and gas supplies, which mostly come from outside Europe, often from politically unstable parts of the world, coal (having a considerable indigenous production) has been seen as a secure and affordable supply source that is not prone to major interruptions and the resulting price and supply risks. Yet coal has never been considered a strategic resource in the same way as oil and gas resources.

2. Presently, 75 countries possess proven coal reserves, and in more than 50 countries coal can been mined. Hard coal together with lignite accounts for no less than about 55% of all fossil energy resources. Between 1999 and 2009, the worldwide total coal production increased by 54% (hard coal +66%). Since 2000, global coal consumption has grown annually by 4.4% - faster than any other fuel. In 2010, global coal consumption was 55% higher than ten years before. Even in the OECD, coal consumption rose by 5.2%; this was the fastest rate in 31 years, and at the same time the biggest increase among all the fossil fuels last year. During the last decade, coal use (1.7 billion tce) has increased more than any other primary energy source (RES only 0.2 billion tce). Although the relative increase in renewables (excluding hydro) - 210% during 2000-2010 - surpassed that of coal (coal +48%; natural gas just +31%), in absolute terms its contribution still only accounts for just 1.3% of worldwide primary energy demand in 2010.

3. The coal proportion of 28% in the global primary energy mix is the highest since 1971. Coal is used primarily for power generation in power plants in the base and medium-load range. The share of coal in global energy consumption has increased from 25.6% in 2001 to 29.6% (hard coal 27,6% and lignite 1.8%) in 2010 (renewables/RES still just 1.8%), despite the global efforts to mitigate the effects of climate change in the framework of the *Kyoto-Protocol*. For global power generation, coal remains the most important energy resource, with a share of almost 41% in 2010.

4. But coal's high CO2 emissions will have to be reduced significantly in the future by increasing the energy efficiency of existing coal-fired plants and by introducing *Carbon Capture and Storage (CCS)* as well as other clean coal technologies. Due to the interrelation between improving energy (supply) security and mitigating climate change, these two policy objectives can conflict with each other: the expanded use of domestic coal, for instance, can strengthen energy supply security, but will also increase CO2 emissions. Achieving only a 5% reduction in emissions through a switch from coal to gas (in particular pipe-based), on the other hand, will already have a negative impact on energy supply security and the economic competitiveness of economies and national enterprises. Furthermore, it is largely overlooked that the problem of methane emissions (considered 20-25 times more harmful for the atmosphere than CO2 emissions) during the exploration and long-distance transportation of natural gas (e.g., via a rapidly aging and leaking Russian pipeline network) is often more severe than the negative impacts of indigenous coal production.

5. **Rivalry with Conventional and Unconventional Gas:** The future of coal in Europe depends primarily on the success of the EU-wide *20-20-20 Programme* and its rivalry with natural gas in the European energy mix. Natural gas produces much less CO2, but has always been much more expensive than coal, having been linked to the oil price basket until very recently. The higher the gas prices and the lower the carbon prices, the better the future for coal, even including CCS. But the (r-)evolution of new drilling technologies for unconventional gas - together with the global decrease of gas demand alongside the worldwide economic-financial crisis of 2008-2010 and the increased output of LNG - has created a global gas glut that has reduced international LNG prices and led to a de-linkage of gas from the international oil price. Due to the expanded availability of conventional and unconventional gas resources from once 60 years to meanwhile more than 250 years, and it being the cleanest of the fossil fuels, the demand for natural gas will grow more rapidly than for other fossil fuels and

result in a worldwide *"golden age"* of natural gas.

6. Forecast of Coal Demand and Supply until 2035: In the mid-term, the worldwide coal share will decline to around 32% by 2035 *(New Policies Scenario/NPS)*, but the use of coal in volumes may rise up to 65%, depending on which of the three different IEA scenarios is assumed. The forecasts of the future global demand for coal are the most uncertain ones (as they hinge on the *"ultimate uncertainty"* of China's coal policies). Consequently, the corresponding scenarios of future worldwide coal consumption diverge significantly by 2035. Thus, the latest IEA projection has projected that the share of coal in the global energy mix will decrease from 27% in 2009 to 24% *(New Policy Scenario)* or even 16% *(450 Scenario)*. In the world electricity generation, the coal share will be reduced from 41% in 2009 to 33% *(New Policy Scenario)* or down to 15% *(450 Scenario)* in 2035. But the power sector will remain the main driving factor for the world's rising coal consumption and is responsible for around 75% of the growth in global coal demand by 2035. In this context, most public energy debates overlook that new coal production and coal transformation options for liquefying or gasifying coal are underway for commercial operation. Another "silent revolution" for *"King Coal"* (i.e., *Underground Coal Gasification/UCG)* - similar to the development of new drilling technologies in the U.S. that has enabled the production of unconventional gas resources –cannot be excluded in the years to come. But also new coal options such as Coal-Bed Methane (CBM) and *Coal-to-Liquids (CTL)* need to include CCS for the reduction of CO2. For CTL, CCS is rather inexpensive because CO2 is already being produced with the syngas, and the bulk of the CO2 needs to be captured anyway. But CCS is also seen as the only realistically available technology for other fossil fuel resources (including unconventional oil) and energy-intensive industries (paper, chemicals, cement, steel, etc.) for meeting the longer-term reduction of GHG-emissions by 2050. However, the future production of electricity from coal conversion/combustion with CCS will never be as cheap as coal plants without CO2 emissions today. Still, the widespread deployment of advanced coal technologies in both the energy sector as well as energy-intensive industries could not only increase their efficiency, but could also both reduce the demand for and increase the use of coal, just as breakthroughs in CCS technologies could also boost the worldwide use of coal.

7. China and Global Coal Demand: During the last years, China has not only surpassed Germany as the world's largest exporting nation, but also Japan as the second largest economy in the world, and even the U.S. as the world's largest energy consumer. While China's energy demand in 2000 was only half that of the United States, China may consume up to 70% more energy than the U.S. by 2035. Between 2000 and 2008, the increase in its energy consumption was four times higher than in the previous decade. Together with Australia (the world's largest exporter of hard coal), China has also become a leading nation in the promotion of clean coal technologies and is supporting new technology options such as CCS, CTL and CBM. China, India and Indonesia together are expected to account for almost 90% of the total growth of the worldwide coal demand. By 2035, China will account for half of the global coal production and install around 600 GW of new coal-fired power generation capacity – which is equal to the combined coal-fired generation capacity of the Unites States, the EU and Japan. China has also become the largest source of Greenhouse Gas Emissions (GHGE) since 2006. There are already four CCS-projects underway in China, three of which are in the power sector, intended as a demonstration of CCS with state-of-the-art *Integrated Gasification Combined Cycle technology* (IGCC). The introduction of clean coal technologies by refurbishing existing coal plants becomes important not just for China itself, but also for the rest of the world if any international mitigation policies for climate change are to be successful. While new power plants have a thermal efficiency as high as 45%, China's and India's average thermal efficiency of their power plants is still just 27-29%. Although China is currently building more state-of-the-art efficient coal plants than the U.S. or Europe, only 60% of all newly built coal plants can be considered modern and highly efficient.

8. Fossil Fuel/CO2-Emissions: Energy-related CO2 emissions are projected to rise by 20%, from 30.4 Gt in 2010 to 36.4 Gt in 2035. This will lead to a global warming of more than 3.5° C, rather than the target of 2°C aimed for in the Kyoto-process. In 2010, the energy sector produced around 65% of all worldwide GHG emissions. This share will further increase up to 72% by 2035. In the energy sector itself, fossil fuel-based power plants and heavy industries are the largest emitters of CO2. They currently account for around 52% of total CO2 emissions worldwide – equaling around 15 Gt of CO2 annually. A single 1,000 Megawatt (MW) power plant produces 6 mt of CO2 per year. At present, modern coal plants reach an efficiency of up to 45% (worldwide average is around 30%) and thus contribute to the reduction of CO2 as part of the worldwide efforts for mitigating climate change. But this can only succeed if a radical and far-reaching transformation of production and the use of energy takes place *worldwide*. Because of growing worldwide coal production and consumption, coal remains the largest source of global CO2 emissions.

9. Carbon Capture and Storage (CCS): CCS is a system of technologies that *integrates three stages: CO2 capture, CO2 transport and geologic CO2 storage.* For each of the three stages for the CCS value chain, various technologies and different options are available. Most of them have already been tested for years, if not decades. But none of the existing large-scale projects involved the capture and storage of CO2 from coal-fired plants or industrial plants in energy-intensive industries such as cement, chemicals, metals, pulp and paper. Full-scale CCS demonstration projects are expensive, with costs of up to USD 1 billion. But the challenges of integration and scale can only be overcome through the experience of building and operating those demonstration projects at commercial-scale CCS facilities.
Technologically, three major CCS-development projects for the *capture of CO2* are being pursued and tested: two post-combustion CO2 capture projects (steam power plants: conventional power plant with CO2 scrubbing and with an *Oxyfuel process)* and one pre-combustion CO2 capture in combined-cycle plants based on the *IGCC* process. Up to now, no clear winner has emerged out of the technological competition as all three technologies proved to be successful and mature. Moreover, the concrete capture costs for the application of the individual technologies depend on the specific conditions of the capturing processes and the plant.
For carbon storage, the following options are available:
(a) Saline aquifers on land or below the seabed;
(b) depleted oil or gas fields as well as coal seams;
(c) Enhanced Oil and Gas Recovery (EOR/EGR) or other industrial use options currently being researched; and
(d) storage in deep sea sediments (two methods can be used for different water depths of at least 1,000 and 3,000 meters, respectively).
If underground storage of CO2 is not possible where it is produced, it must be transported to adequate sites for storage inside the country or to other countries.

The only available and critically enabling technologies today that address the need for curbing GHGE (i.e., CO2) are either (a) various technological options for increasing the efficiency of power plants and/or (b) CCS to help reduce CO2 emissions significantly. CCS is presently the only technology that can capture at least 90% of the emissions from the world's largest CO2 emitters. It combines the advantages of allowing continued use of domestic resources while being relatively more advanced than many other alternative technologies under development. While the technique to capture and store CO2 has already proven successful, the technology along with its risks and benefits also needs to be tested in large-scale demonstration projects, which will come online in 2015. The commercial rollout of CCS in electricity generation, however, is currently not expected to take place before 2020, followed by a global spread of implementation around 2030.
The world needs to build 3,400 commercial projects worldwide by 2050 if CCS is to provide 20% of the CO2 reductions required for effectively containing the effects of climate change and preventing a temperature rise of more than 2° Celcius. The introduction of CCS on a significant scale on national, EU- and global levels will require the construction and operation of a large infrastructure of pipelines, surface injection facilities and monitoring and analysis network. In 2010, governments worldwide made commitments to support the launch of 19-43 large-scale CCS integrated demonstration projects by 2020. The same year, the *Global CCS Institute* already identified 80 large-scale demonstration projects at various stages of development worldwide. By the end of 2010, 234 CCS projects were active or planned.

3.2 EU-COAL POLICIES AND THE ROLE OF CCS

3.2 EU-Coal Policies and the Role of CCS

10. EU-Coal Demand 2008-2035: According to the IEA's *New Policies Scenario,* the EU-27 coal consumption 2008-2035 will decline annually by -2.5% (Europe at large: -1.7%) or even -3.8%, which mirrors the EU's ambitious climate goals of its common energy policies. The share of coal in the EU's future energy mix will decrease from 16% in 2009 to just 8% in 2035 *(New Policy Scenario)*, or even 6% *(450 Scenario)*. In the EU's electricity generation, the coal share will be reduced from 27% in 2009 down to just 10% in 2035 *(New Policy Scenario)* or 5% (450 Scenario), respectively. However, the projections depend on whether the share of nuclear power is maintained, only marginally reduced *(New Policy Scenario)* or even increased *(450 Scenario)*. Nonetheless, the EU's collective energy mix will rely heavily on fossil fuels, including coal. Coal, being primarily an indigenous energy source, will still play an important role in both the total primary energy demand as well as in power generation and, thus, will enhance the EU's and *Central Eastern Europe's (CEE)* energy security even through 2035. Europe also continues to need both coal and nuclear power for the expansion of renewable sources, which requires a reserve power (when wind and sun are not available) in order to secure a stable base-load.

11. EU-Coal Reserves: In Europe, only Poland has significant hard coal reserves with 12,726 mt (=1.8%, worldwide ranked 9th). Altogether, the EU-27 have no more than 2.2% of the worldwide hard coal reserves. Germany has the second largest lignite reserves (after Russia) in the world, followed by Australia, US, China and India. Following these are other European countries, namely Serbia (rank 7 with 2.6%), Poland (1.3%), Greece (1.0), the Czech Republic (1.0%) and Hungary (0.9%), which all rank in the top 20 regarding lignite reserves.

12. EU-Coal Production and Consumption: Within Europe, hard coal is produced in Germany, Poland, the Czech Republic, Bulgaria, Romania, Spain and the United Kingdom. Lignite coal is mined in Germany, Poland, the Czech Republic, Hungary, Slovakia, Bulgaria, Slovenia, Spain and Greece. Germany is still the world's largest brown coal producer (with a share of 17.2%), followed by China and Turkey. The EU-27 produces just 2.3% of the global hard coal (133 mt in 2010). Poland (rank 8 with 5.6%) and the Czech Republic (4.6%) are also included in the list of the top 10 global lignite producers. Focusing on economic-political groups and regions, the EU-27 combined are the world's largest producer of lignite/brown coal (396 mt in 2010) with a share of 41.4% (all of Europe 54%). Meanwhile, the EU-27 consume just 4.9% of the global hard coal demand, but account for 41.8% of the global brown coal consumption.

13. Rising Import Dependency of Coal: Often overlooked, *the EU-27 are the largest importers of coal in the world (188 mt in 2010)!* While coal is available in international markets at relatively stable prices and is a much cheaper fossil fuel than gas and oil, the growing dependence on coal imports overlooks some important strategic trends in the context of future coal supply security. Although worldwide coal reserves are much more spread out across the various regions and countries, and not concentrated in a few countries and regions like the remaining conventional oil and gas reserves (like in the *Strategic Ellipse* of the Greater Middle East), *international trade involves only 17% of the entire global coal production.* Most of the coal production is being used in the producing countries themselves. The volume of seaborne coal trade, steam coal and coking coal will continue to rise through 2025 due to the coal demand in non-OECD countries, predominantly in China and India. The share of coking coal imports for the Asia-Pacific countries will rise from 62% in 2008 up to 70% by 2035. Although China, with its third-largest coal reserves, will continue to rely overwhelmingly on its own domestic coal mines and supplies, it will also remain dependent on rising coal imports of up to 3.7 quadrillion Btu. Moreover, India's coal imports will be four times the 2008 level.

Europe's coal imports accounted for around 29% of the global coal trade in 2008. By decreasing this share to around 25% in 2020 and just 20% in 2035, Europe will also lose significant market shares and competitive power towards both its Asia-Pacific import rivals and Asian coal exporters like Australia and Indonesia. The present situation of the international coal markets has often been projected into the future in forecasts without accounting for the already changing dimensions of, and the resulting implications for, the international coal markets already underway. In the future, confronted with China's, India's and the world's rising demand for coal, hard and brown coal prices will further rise and fundamentally change the international coal markets.

While in the past it has been argued that the remaining coal reserves will last much longer (around 150 years in 2006) than the remaining conventional oil (40 years) and gas (60 years) reserves, based on present production levels, what has been overlooked is the fact that the *Reserves-to-Production ratio* has undergone a drastic decline during the last decade, from 210 years back in the year 2000 to just 118 years of global production in 2010; this trend will most likely continue in the years and decades to come.

The largest share of coal reserves are concentrated in the five largest territorial countries of the world, namely the U.S. (with 27.6% of the global coal reserves), Russia (18.2%), China (13.3%), Australia (8.9%) and India (7.0%) – together accounting for over 75%. These countries are followed by the only European country having considerable coal reserves, namely Germany with 4.7%, (Poland has 0.7%, which has the sixth-largest coal reserves in the world). The five largest coal reserve holders together control an impressive 57% of the entire world coal reserves. Global *hard coal* resources are even more concentrated, with about 83% (and around 76% of all reserves), in the U.S., China and Russia.

Moreover, of the five largest coal reserve holders neither the U.S. nor China nor India is among the leading exporters of coal. The world's largest exporters of *steam coal,* who with a market share of 70% dominated the international coal trade in 2008, were Indonesia, South America (primarily Colombia), Russia, and southern Africa (mainly South Africa). For coking coal, Australia, the U.S. and Canada ranked as the three largest exporters in 2008 and are expected to retain their positions through 2035. Besides Vietnam and China, Poland is expected to decrease its coking coal exports over the mid-term because of geological difficulties.

While China, the U.S. and India are the leading coal consumers, they also see coal as a strategic reserve of fossil fuels (particularly China). All three are expected to increase their use of coal for electricity generation. Besides relying on existing plants, current planning especially involves new cleaner and more efficient power plants that will be combined with the expansion of CTL-plants, at least toward the end of the projected mid-term period, including in the U.S.

While Russia has become not just the most important import source for Europe's oil and, particularly, gas demand, which raises numerous concerns for the EU's energy supply security, it has also become a more important source for Europe's (i.e., Germany's) coal imports. By overcoming some of its rail bottlenecks, Russia was able to increase its seaborne coal exports three times between 2000 and 2008, totaling 76 mt in 2008. But in the future, the share of coal for total energy consumption will increase slightly from 14% to 15% as well as its share of electricity generation from 23% to 24%. Although natural gas will remain the leading source for electricity generation, nuclear power and coal-fired power plants will see an increase in their share for electricity generation and together account for no less than 68% of the country's electricity generation growth by 2035.

In September 2006, Germany's decision to phase out its hard coal production by 2017 had the direct impact on President Putin's policy of increasing the share of coal in Russia's future energy consumption. Confronted with a looming gas crisis at home, he wanted to use the country's gas reserves for Europe's and Germany's rising gas imports, which were guaranteed to follow the phasing-out of hard coal. While Germany's decision will reduce its CO2 emissions more drastically within the next decade, it will effect higher CO2 emissions in Russia because Russia's coal-fired plants have on average a much lower efficiency than Germany's. It is an interesting example of the free-rider phenomenon and how national energy policies have direct and indirect impacts on those of third countries if they do not think more strategically.

While Europe (i.e. Germany) is presently also dependent on high coal imports from Australia, Indonesia and South Africa, it is questionable whether it can continue to import coal from these Asian-Pacific countries in the mid- and long-term future, given the rapidly increasing coal demand of China, India and the entire Asia-Pacific region. Meanwhile, China became not only a net importer of coal, but has also for the first time imported seaborne trade coal from South Africa and even Colombia, both of which have historically been considered Atlantic suppliers. The European and EU market shares are already continuously declining alongside a power shift toward the new consumer centers in the Asia-Pacific, as China, India and others will restructure and re-define the international trade patterns and structures of the global coal markets in the years and decades to come. Thus, European coal prices are increasingly influenced by the rising demand for coal in China and India.

Moreover, the future supply situation of internationally traded coal and price levels will also depend on the future market concentration and cartelization tendencies of international coal markets; a trend toward more concentration and coordination could already be observed during the last decade. Thus, future coal markets could be controlled by ever fewer international producers, which could divide and control the international coal markets between them. So far, however, the cartelization and the state-governed re-nationalization of the coal sector (exception: Venezuela) are not comparable to the developments in the worldwide oil and gas sectors. Still, a certain trend towards a further concentration and cartelization process can be observed – especially in terms of global trade patterns: In 2009, the 25 leading coal companies accounted for about 35% of global production and 50% of global trade. Even more striking are the concentration processes by the largest hard coal producing companies: 30% of the steam coal traded by sea and 47% of the coking trade by sea are controlled by the so-called *"Big Four"* of the *RBXA-Group,* namely *Rio Tinto, BHP Billiton, Xstrata/Glencore International* and *Anglo Coal.* These trends will further increase, given China's plans to merge its own coal producing companies. Whereas in 2007 only 13 truly large coal companies existed in China, four of them were already among the top 12 global coal producers.

Given these new strategic developments on the international energy markets and the manifold uncertainties and growing risks of fossil fuel supply, domestic coal reserves and indigenous production processes using clean coal technologies (including CCS) can contribute significantly to an enhanced energy supply security of the individual EU-member states as well as the entire EU-27. Therefore, Europe should refrain from closing down domestic coal mines hastily out of short-term considerations that overlook or neglect new strategic developments on the global coal front and other markets, as well as new promising state-of-the-art clean coal technology innovations. In examples in the UK and Poland, coal mines were closed prematurely and were only re-opened because changing market conditions and prices as well as new technologies made it possible to produce at a competitive level. Yet it was only possible because the mines had not been completely closed but only mothballed. Once deposits are fully closed, re-starting operations is often hampered by a number of causes including long-lead times, the loss of mining workers, experts, experiences and (management) skills, and the need for high investments, which all together often make the entire project unrealistic .

14. Underground Coal Gasification (UCG): In comparison with *coal-bed methane (CBM),* UCG offers an even greater potential to recover energy at *"unmineable"* coal deposits with rather conventional technologies. UCG would also significantly increase the world's classified recoverable coal resources. New cost analyses suggest that combining UCG gas as a substitute for natural gas in *Combined-Cycle Gas Turbines (CCGTs)* for power generation with a carbon capture technology (pre- or post-combustion carbon capture) is potentially even more competitive than feeding natural gas to *CCGTs* or any other form of low-carbon power generation. UCG has the big advantage of leaving a much smaller surface footprint, as it allows waste and ash to stay underground and does not emit methane or contaminate water because no fracturing drilling technologies are used like in shale gas exploration.

15. Clean Coal for Europe: As part of its pro-active climate protection policies, the European Commission in tandem with coal industries and the coal-fired power station operators pursue a *"Clean Coal Concept"* based on an integrated approach of modernization that promotes the introduction of state-of-the-art technologies to raise the efficiency of coal power plants above 50% for new coal-fired plants and to reduce CO2 emissions from electricity generation plants with CCS-technologies after 2020. Although the new *"Energy Strategy 2020",* adopted by the European Commission on November 2010, confirms the decarbonization policy, it also supports indigenous fossil fuel resources, and, along with it, a sustainable coal sector for the EU's future energy security and as part of a broad and diversified energy mix.

CEEP has made the proposal to permit immediate investments in coal power plants and to consider all aspects of coal usage as well as to extend the derogation period for new coal power plants with an efficiency of at least 45% by granting a minimum 20 years from their operational date. This derogation period should be shortened when the complete CCS technological chain is available, both economically and commercially.
If such solutions are adopted immediately, it will allow investors to start their investments and to contribute towards efficiently solving in-coming energy problems in the EU countries, thereby fulfilling EU energy objectives.
Many power plants in Europe still apply old technologies, but one may state that the average energy efficiency for these power plants is calculated at a level of around 30%. New technologies available on the market can reach energy efficiency levels of 45% or more. This means that if we replace old power plants, the decrease of CO2 emissions is at the level of around 30%, which is a very encouraging figure. Thus, limits in the power plant sector prescribed in the European Strategy *"Energy 2020"* could easily be reached or even surpassed.

16. EU and CCS: CCS is seen by the Commission as well as by most international experts as a key technology in addressing the global climate challenge by reducing global emissions significantly while keeping coal as an important fossil fuel in the future European and global energy mix. The *European Council* welcomed the Commission's proposals for CCS and the *construction of 12 demonstration installations in the EU-member states.* Currently, six large-scale CCS projects are under construction to demonstrate the technology, particularly in electricity generation. The Commission has declared to co-finance these projects with up to €1 billion in total. Another funding mechanism, as part of the EU's *Emission Trading System (ETS),* became operational in November 2010. Together with the European Commission, major electricity companies in Europe have created the *"Technology Platform Zero Emission Fossil Fuel Power Plants (ZEP)",* a knowledge-sharing network for large-scale CCS demonstration projects that has developed a strategy for research and implementation of CCS in the field of electricity production. The European Commission has also intensified its discussion and knowledge sharing with stakeholders through its *"European Fossil Fuel Forum" ("Berlin Forum"),* which also set up a *"CCS Project Network"* as an advisory forum and for promoting timely progress of large-scale demonstration projects.

The implementation and commercialization of CCS is complicated by the fact that potential storage sites are not evenly distributed across Europe. Thus, it is it not only necessary to demonstrate the technologies and higher levels of de-carbonization at large-scale demonstration plants, but also to build infrastructures of pipelines across the borders of member states along with a shipping infrastructure, if countries do not have adequate or sufficient CO2 storage potential.
Challenges and Perspectives of CCS

3.3 CHALLENGES AND PERSPECTIVES OF CCS

3.3 Challenges and Perspectives of CCS

17. EU-Wide Storage Capacities: European storage capacities as a whole are not considered a major problem because the available storage space is estimated at 300 Gt, while the total volume of CO2 through 2050 was estimated at 18 Gt. Aquifers can store up to 60-80% of the total amount of CO2. Consequently, aquifer exploration is seen as one of the most urgent tasks in the coming years, particularly in the North Sea. Poland and Belgium may need to send part of their CO2 to the Netherlands and Germany. Hungary and Romania do not have sufficient national storage capacity, but storage in Slovakia could be an alternative for these countries. Yet relying just on offshore sites because of lacking public acceptance in Europe would either result in very high costs for the entire CCS chain or render CCS impossible for large parts of Europe. For CEE countries, it is important to recognize that at present Eastern Europe lacks sufficient storage capacities (with the notable exception of Slovakia and to some extent Poland). Without more geological research into potential storage sites, the CEE countries will need to build an extensive infrastructure network. But the need for cross-border transports of CO2 is also an excellent opportunity for sub-regional and regional cooperation. The CEE countries should also look into the option of a regional *CO2 hub* (i.e., between Poland and Slovakia), as regional cluster figures suggest.

18. EU-Wide Transport Needs and Challenges: Given the uneven distribution of subsurface storage reservoirs *(sinks)* for Europe, the captured CO2 needs to be transported to adequate storage sites inside the country or beyond its national border. Transport costs may not be the biggest cost factor in the CCS chain of application, but it requires intensive planning for the development of the transport infrastructure. An EU research report also highlighted that only a collective use of infrastructure for neighboring sources will reduce costs and decrease risks.

The total length of the CO2 pipeline network, including both onshore and offshore storage sites, was estimated at about 22,000 km by 2050. The total transport distance for the Offshore-scenario (because of public opposition, CO2 would only be stored offshore in the North Sea) would be 50% longer. Germany, Norway and Poland would have to construct the largest amount of the pipeline network. Cross-border transport of CO2 would start in the Reference-scenario (with on- and offshore storage sites) around 2030, while in the Offshore-scenario it would already be needed around 2020.

19. Legislation and Regulatory Requirements: Internationally, the biggest progress in establishing legal and regulatory frameworks was made in Australia, the EU and the U.S. during the last years. In the EU, *the Directive on the Geological Storage of CO2,* and the *EU Emissions Trading Scheme* provide the framework for legislation and regulation of CCS within the region. They must be transposed into national law by each member state this year. The *IEA's International Regulators' Network* also served as a forum for CCS regulators, policy makers and other stakeholders. In 2010, they developed a *Model CCS Legal and Regulatory Framework* as an instrument for countries drafting their own CCS legislation.

20. Costs and Financial Challenges: The costs of inaction and not implementing CCS will be over 70% higher if the world fails to address climate change in the coming years and believes it can postpone an active climate protection policy well into the future. But the financial gap for CCS has not really been narrowed during the last years due to continued uncertainties on the future of the international climate protection policies and insufficient price signals. For the rapid development of large-scale demonstration projects and the following commercialization of CCS-technologies, particularly in power generation, the financial gap between the additional costs for CCS above a conventional plant, being higher than the revenue from the relevant market and the additional benefit from CO2 reduction, could not be overcome. However, governments and industrial leaders need to face long-term strategic challenges. With further development, knowledge-sharing, industrial competition and technological innovation, these costs will decline as the revenue from the relevant markets and the benefit for CO2 reduction grows. Public-private partnerships involving the appropriate sharing of costs and risks will be required particularly for near-term projects.

Most importantly, as the technology matures in all three stages of the CCS-process, the type of financing should be replaced increasingly with a mechanism that creates value for CO2 emission reductions achieved through CCS. In this context, it would be most useful to increase government funding and to expand public-private partnerships for R&D projects using CO2 as an industrial good for *Carbon Capture and Use (CCU).* Currently, the inclusion of CCS increases the capital cost of a newly-built coal-fired power station by 70% and the required fuel by 40%.

In addition, transportation and storage costs need to be included. If beyond 2025/2030 gas-fired power plants are refurbished with CCS, the comparative costs of coal versus natural gas carbon capture will depend in part on the coal-to-gas price ratio. It is often argued that coal produces more carbon per unit of electricity than natural gas. Thus the carbon abatement (Euros per ton of CO2 captured) is benefiting coal. However, natural gas has two other advantages:

(1) The capital costs for gas carbon capture are estimated at €2,260 per kW, compared with €4,330 per kW for coal; and

(2) the costs of storage will be lower because for each unit of power generated, natural gas produces approximately half as much CO2 as a coal plant, reducing the costs of CO2 storage from a gas plant to almost half those from coal.

However, those cost projections depend on a number of conditions, such as the price differential between coal and natural gas, the future technological innovation as well as the opportunities and potential revenues for *CCU.* Besides the cost factor, coal with CCS has a big advantage for many EU member states (like CEE countries, e.g. Poland) over gas with CCS, which is security of supply as an indigenous energy source, with the exception of potentially indigenous unconventional gas (as in Poland).

Two new ground-breaking studies by *Alstom* and *ZEP* in June and July 2011 both came to the conclusion that integrated CCS-projects for coal-and gas-fired plants are becoming cost-competitive towards all other low-carbon options of electricity generation, despite the fact that present CCS technologies reduce the degree of efficiency of coal-fired plants by 10-50%, depending on the CCS method used. Compared with other mature technologies, the greater potential for the improvement of CCS through learning will increase its competitiveness over time, particularly through the introduction of second- and third-generation technologies. Given the right policy framework, neither the technology nor the costs are themselves obstacles to CCS deployment. Furthermore, all three CO2 capture technologies (post-combustion, pre-combustion and oxyfuel) were analyzed and there is currently *"no clear difference"* in the associated costs. They could all be competitive in the future once they have been successfully demonstrated. The main factors influencing total costs are considered to be fuel and investment costs.

Early strategic planning of large-scale CO2 transport infrastructure will also reduce final costs because the scale of this infrastructure is only matched by that of the current hydrocarbon infrastructure. In regard to the specific storage costs, location and type of storage site, reservoir capacity and quality are the most decisive factors for the ultimate costs of CO2 storage. Here, onshore is cheaper than offshore; depleted oil and gas fields are cheaper than deep saline (aquifers); larger reservoirs are cheaper than smaller ones; high injectivity is cheaper than poor injectivity. In the short-term, an estimated US$5-6.5 billion per year is needed to cope with the additional investment costs of CCS over the next decade, according to the IEA.

21. Prospects for *Carbon Capture and Use (CCU):* The present focus of international CCS-projects and cooperation is directed too much towards the permanent storage of CCS underground in geological formations, where it is treated as a waste product. In the coming years, it should, instead, be recognized as an industrial good that can be utilized. This would have many advantages, such as reducing the burdensome costs of the CCS de-carbonization effort, decreasing the storage volumes and using the storage sites not as a final deposit, but rather as an interim storage that leaves the possibility of further industrial use of CO2. It could even turn the costs of storage into a revenue flow to support CCS projects' economics.

Traditionally, the use of carbon capture has been associated primarily with coal-fired plants because they have the highest emissions. But the technology could later also be applied to gas-fired and biomass plants as well as other energy-intensive industries. The most obvious use of CO2 is for *Enhanced Oil and Gas Recovery (EOR/EGR),* which is a well-proven technology in the U.S. but has not been applied in Europe.

In the U.S. beneficial uses of CO2 have financially already offset CCS implementation costs in some cases, albeit they might not be universally applied for the time being. According to some estimates, Europe may be able to absorb between 4-11% of its current emissions. However, given the experiences of international oil companies in the U.S., the potential for using CO2 could also be much larger; and given the difficulties international oil companies experience in getting access to the remaining conventional oil and gas resources, CO2 could enhance the recovery of conventional oil and gas resources by up to 50%, an interesting prospect compared to the alternative of exploring new and much more expensive fields. Furthermore, the injection of CO2 could be a very interesting option for the hydraulic fracturing of unconventional sources of energy (i.e. shale gas) as *EXXON* has tested in Germany. But also other CO2 applications may provide a future revenue flow, including fertilizer, food, and synthetic material production, and for algae-based fuels, which is being tested in Israel, Germany and in the U.S. by the Pentagon.

22. The Public Acceptance Challenge: While the worldwide trend toward large-scale CCS demonstration projects and R&D programs has solidified, the expansion of EU CCS projects has slowed down. Although the costs for the suggested CCS projects have been increased by 20-30% during the last 3 years, it is not so much the higher costs or any technological uncertainties that caused the slow-down. The real reason is the lack of high-level political support and public acceptance. This is the result of a combination of environmental concerns, such as contamination of water and suffocation if large quantities of CO2 should leak out. Critics of CCS have also argued that CCS is a pretext for a continued use of coal in energy consumption at the expense of the rapid expansion of renewables. Furthermore, NIMBY-attitudes are rising on the local level across Europe and complicate any planned larger energy infrastructure program. The European Commission wanted to fund 12 large-scale CCS demonstration projects by 2015, but currently only six demonstration projects are underway.

In the Netherlands, local resistance has prevented a plan to store CO2 under a residential neighborhood near Rotterdam, leaving only the alternative of an offshore storage site, which is, however, a much more time-consuming and more costly option for the future. In Germany, a national CCS law has been adopted by the government and parliament. But federal states have a veto right and most stakeholders are skeptical that any real operating commercialized CCS storage site can ever be started. But this is only one example in Germany among many, as all larger energy projects were equally blocked (even RES). At the same time, CCS appears no longer high on the political agenda of EU governments (similar to the Kyoto climate policy), making its future all the more uncertain. Currently, public energy debates often involve superficial exchanges, with a low quality of information, which is why public and social acceptance will be the major challenge for governments and major stakeholders alike in the years ahead in Europe. As a matter of fact, public acceptance has become a fourth pillar of the *"Energy Triangle" ("Energy Trilemma").* It is at the same time an area where EU member states need to strengthen their exchange of experiences and expertise with their European and North American CCS partners.

The need for a pro-active engagement policy, based on transparency and credible as well as timely information, vis-a-vis the local population has been highlighted by a survey about awareness and acceptance of CO2 and CCS conducted in 12 European countries: Germany, United Kingdom, Italy, Spain, the Netherlands, Poland, Finland, France, Greece, the Czech Republic, Bulgaria and Romania. The survey highlighted the different levels of publicity about the projects, including within the six member states where large-scale CCS demonstration projects are underway (the Netherlands, UK, Italy, Spain, Germany and Poland). It often confirmed the inaccurate and/or superficial knowledge about CCS. But it also showed that those who were more knowledgeable about CCS were also those who have fewer concerns and who felt that CCS was effective, that they would benefit from CCS and could trust the EU. However, it should not be overlooked that the application of large-scale CCS demonstration projects is going ahead in Norway, Great Britain and, more slowly, in Poland.

3.4 CEE-COUNTRIES' COAL AND CCS POLICIES

3.4 CEE-Countries' Coal and CCS Policies

23. Czech Republic: While the Czech Republic is less dependent on energy imports than most other EU member states, including its CEE neighbors, it is structurally rather unbalanced; its oil and gas dependence is rather high with 97% and 96%, respectively. But most of its coal and uranium demand is produced domestically. In 2008, it imported some 1.1 mt of hard coal, predominantly from Poland. While hard coal production will rapidly decline after 2020, brown coal will not decrease as fast. But in the future, the overall import dependence is expected to grow from 32% of its entire energy demand in 2009 to almost 50% by 2020. The most dominant energy source is coal with 41%, natural gas with 19% and oil with 20%, supplemented by nuclear energy with 17%, as well as renewables (5.4% in 2008, mostly biomass and waste) and hydroelectric power with together 6%. Coal is the only significant domestic energy resource, estimated at approximately 2 bt. Brown coal accounts for more than 70% of these reserves, but hard coal is exported in significant quantities to Slovakia, Austria, Poland, Germany and Hungary.
Similar to Poland and Hungary, the per-capita emissions are still higher than the EU-average; in fact, they are the second highest in the IEA after Australia. Because of the dominance of coal in its energy mix, the energy sector accounts for 40% of the total GHGE in the Czech Republic, which is higher than the respective EU-average. By 2020, it seeks to reduce its CO2 emissions by 20% and the total aggregate CO2 emissions by 25%, compared to the 2000-level.
The Czech brown coal industry has always played an important role in the national economy. According to the updated *National Energy Concept,* coal is expected to remain an important energy resource in the Czech Republic until 2030. But for long-term planning, coal is expected to fall from 60% to about 12% of the electricity generation mix. By contrast, nuclear power will produce 90% of the electricity needs and 80% of district heating.
Presently, the Czech Republic does not have a well-established pro-active CCS-policy, despite the fact that the Parliament has already discussed transposing the EU-CCS Directive into national law, which is now postponed while the draft law is revised. The much-needed investment in CCS at the industrial scale is also constrained by the limited availability of coal as a result of government-imposed limits on coal mining as well as the relatively small storage potential in the Czech Republic. Although the updated new *Energy Concept* mentions CCS, it is sceptical and makes the implementation dependent on *"following the results of completion of these technologies development, validation of their efficiency, and support the advancement of the European market in this area by building them"* instead of promoting a strategically designed, pro-active support policy. Furthermore, any investment in additional, state-of-the-art brown coal-fired plants is dependent on the mining blockade in the southern part of the Upper Silesian basin. The government should also support new coal options, such as *UCG* or the presently limited methane gas production from hard coal mines in Northern Moravia by UNIGEO, UNIMASTER and OKD for local needs.
Given the export-oriented energy policies of the Czech Republic and its favorable geographical location, it could be a driver of more regional and sub-regional energy cooperation policies. Together with Poland, it could also spearhead a sub-regional cooperation policy on CCS, which would not only be important for a future with more clean coal-fired power plants beyond 2020, but also for its gas and other energy-intensive industries beyond 2025/2030.

24. Slovakia: The Slovak Republic has abundant indigenous energy resources, but the majority is not exploitable. As a consequence, Slovakia's energy dependence on imported energy sources is even higher than its CEE neighbors'. It has to rely on oil imports for 80% of its total primary energy supply as well as on gas imports (almost 90% of its gas consumption), and in both cases primarily or even exclusively on Russia (gas). The Slovak energy mix largely relies on fossil fuels (75%), owing to an intense gasification policy, an increased oil use in road transport and the continued use of coal in the power and heat generation sectors. In 2008, the energy mix was still heavily based on natural gas (31%), coal (25%) for electricity and heat generation, followed by oil (17%), nuclear (8%) and RES (3.4%, mainly hydropower). Until 2010, its energy intensity improved considerably. When measured on a per-capita basis, Slovakia is currently less energy-intensive than Poland and the Czech Republic, but still more than Hungary.

In October 2008, the Slovak government approved its *"Energy Security Strategy"*, which will rely more than ever on nuclear power. It especially examined the options for diversifying its gas imports and new underground gas storages. CCS is not explicitly addressed. But many of the government's declarations and outlined objectives in its 2006 energy policy document have not been followed up with an engaged, proactive policy and sufficient funding. While it is understandable that Slovakia pays most attention to its vulnerable gas supply security at a time when the gas share in Slovakia's energy mix will increase, it should not overlook the need, opportunities and strategic perspectives of CCS and the EU's supported demonstration projects, as well as the fact that it is the CEE country that has the most to gain from cross-border cooperation in energy security.

25. Hungary: In contrast to other European countries and its neighbors (Poland and the Czech Republic), Hungary has relatively few energy resources. Hence its import dependency is rather high. The most important domestic energy reserve is lignite, which accounts for about 80% of the country's solid fuel reserves. Counter intuitively, though, its primary energy consumption mix is dominated by natural gas (38% in 2010), followed by oil (26%), nuclear (16%) and then coal (11%). In comparison, the OECD-average of the gas share in the total primary energy supply is just 24%. Moreover, most of its imported gas comes from Russia via only one route. But Hungary is a driving force in Europe in the promotion of new cross-border connections and networks with its neighbors (i.e., *New European Transmission Systems/NETS* and the *Nabucco* gas pipeline) in order to create a larger single energy market with much better investment conditions and to increase supply options in the event of a crisis.

Nuclear energy from its state-owned nuclear power plant at *Paks* (with four reactors) accounted for about 40% of national power output in 2010 and is generating the cheapest power. With a high level of public and political support, the government presently seeks to extend the life span of this plant by another 20 years, which would otherwise successively be shut down by 2017. Plans to add two new 1,000 MW units to the existing nuclear plant are under consideration. It is expected that the updated safety standards will result in higher costs, which may put into question the planned large role for nuclear power in the future. But the timeframe and the concrete role and future nuclear power capacities will have a direct impact on the future of gas- and coal-fired plants. Natural gas used for electricity generation rose to about 32% and accounts for 67% of heat consumption (OECD average: 51%) in 2010. Hungary's rising gas dependence has been a major concern during the last years and has spurred a number of energy security initiatives and infrastructure projects (gas storages, increased reverse-flow capacities and three new gas interconnectors to Romania, Croatia and Slovakia) to diversify its future gas imports as well as to enhance its crisis management system for major gas disruptions, like the ones in January 2009.

Coal has only a market share of 17% in national gross electricity generation. The government hopes to double the RES share to 14.65% by 2020, primarily via the expansion of biomass and increasingly also geothermal energy. Thus the RES will become much more diversified, while electricity demand is projected to increase by 25% during the next 10 years. But the real challenge for its lignite industry will come after 2012, when Hungary will have to decrease its *GHGE* by 21% in its ETS sector. Beyond its ETS sector, it has to constrain its GHGE to 10% above the 2005 levels. But the transition to a low-carbon economy and the decarbonization of the power, heat and transport sectors require a comprehensive strategy, in which the expansion of biomass will not be sufficient. Furthermore, the efficiency of Hungarian power plants is below the EU average.

In its new economic policy plan of January 2010, the government laid out measures to enhance supply security; diversification of resources has a high priority because of the country's declining hydrocarbon production, ageing infrastructures and limited market entry possibilities for new energy players. In contrast to many other EU-member states, it has institutionalized the EU's integrated energy and climate policy by creating a single *Ministry of National Development for energy,* renewables and climate change issues, which had previously been assigned to separate ministries. The new organization of tasks under one roof will certainly offer much better prospects for streamlining more coherent and effective energy and climate protection policies in the future.

Despite the increased coal imports, Hungary's consumption of coal declined over the last decade and coal has become less important to its national electricity production. But this development also increased Hungary's dependence on gas imports. The continuous rise of power demand and oil as well as gas prices along with concerns about increasing gas supply dependence have raised the political and public awareness about the importance of indigenous energy resources and a sustainable supply security. But coal-fired capacity has already declined from 24% in 2000 to presently 15%. Given the low average in thermal efficiency, several coal-fired plants have already been switched to co-firing and entirely biomass-firing plants. Although new state-of-the-art coal-fired plants had been promoted, the economic crisis, a decline in electricity demand, a retail price freeze and higher taxes have in November 2010 led RWE to cancel its plan to build a 440 MW lignite-fired power plant at Mátra, while MVM gave up plans to invest in any coal-fired capacity under the present circumstances. Looking ahead, Hungary needs to spend more in research and development, and enhance their cost-effectiveness. Traditionally, Hungary did not invest much in R&D expenditures and its percentage of GDP is still well below IEA averages.

26. Poland: In 2009, 93% of Poland's energy mix and primary energy supply was dependent on fossil fuels, dominated by coal with 55% (in 1990 it was even 76%), followed by the shares of oil with 25%, gas with 13% and biomass with 7%. Other RES play only a negligible role. Poland's use of fossil fuels has steadily declined from 75% of total primary energy supply in 1990 to 58% in 2004. In 2010, more than 94% of Poland's oil imports and 87% of its gas imports came from Russia. Therefore, coal as the dominant domestic energy source, has traditionally been seen as a key factor of Poland's national energy security.

But in Poland, too, gas demand is projected to grow from 2009 to 2020 by 28%, and even to 52% from 2009 to 2030. Meanwhile, however, Poland's estimated unconventional gas resources have the potential to change the overall situation of Poland's future energy security by changing the national energy mix, reducing its energy dependence on Russia and de-carbonizing its electricity generation. Furthermore, it plans to construct new nuclear power stations with a capacity of about 4,800 MW by 2030, with the first scheduled to go into operation by 2022, in order to increase its national energy security.

With 16.9 bt, Poland has the 9th largest hard coal reserves in the world and the biggest ones within the EU-27. In addition, it has the second-largest mineable brown-coal reserves (almost 15 bt) in the EU, after Germany. It is also Europe's 9th largest hard coal producer and, after Germany, the second-largest lignite/brown coal producer. However, its recoverable hard coal reserves accessible from existing operating mines are declining very fast, while public opposition has it made difficult to obtain planning permits to open new mines for coal exploration. But due to the role of coal in Poland's present energy mix (with 52%), and in particular in electricity generation (accounting for more than 90%), it will also play a significant role in its energy mix in the mid-term as a domestic, rather inexpensive fossil energy source for its energy security strategy and as part of new base-load coal-fired *Combined-Heat-and-Power (CHP)* plants to bolster the expansion of RES. Nonetheless, the share of coal will decline, as indicated in all of the IEA's three forecast scenarios. Moreover, since 2008 Poland has been a net importer of coal due to its declining production rate.

Nonetheless, coal's crucial role has been confirmed by the official *"Energy Policy of Poland until 2030"* government document, adopted in November 2009. CCS is being mentioned as one of the measures applied to mitigate the environmental impact of the power industry. A major challenge for its coal industry is its old infrastructure- more than 50% of all power plants are over 25 year old and another quarter has been in operation for over 30 years. Only the lignite power plants can be considered modern. In addition, a more efficient infrastructure is available for its coal mining industry and export sector, with cross-border rail links to neighboring countries and to Baltic Sea ports for its exports. Overall, the efficiency of the Polish economy calculated as GDP per energy unit has remained twice as low as the European average, despite the fact that GDP energy intensity decreased by 30% within the last decade.

The Polish government concluded the transposition of the CCS-Directive into its Geological and Mining

Law. The first Polish CCS demonstration project in Belchatów, with support from the EU, is being carried out by the *Polska Grupa Energetyczna, (PGE), PGE Elektrownia Belchatów SA oraz Zaklady Azotowe Kedzierzyn SA.* But the CCS project is dependent on national funds to support it, with total costs of €626 million. It is also hindered by the lack of public support. The conducting of tests of the geological structures identified as potential storage sites are blocked by protests of local organizations, which forced the *Polish Geological Institute* to shift its work on different sites. A second pre-combustion CCS demonstration project is planned by *Zarklady Azotowe Kedzierzyn SA (ZAK)* at a proposed poly-generation plant on the company's *Kedzierzyn* chemical works. Therefore, the carbon price will be crucial in the further discussion of large-scale CCS development projects in Poland.

While the economic viability of CCS is still uncertain across the globe, it will be important for Poland to continue research, pilot and demonstration work in this field as part of the overall EU demonstration projects. With its huge and excellent CCS R&D potential, Poland could more forcefully try to assume a regional leadership role and to promote cross-border cooperation projects by applying CCS-technologies and promoting further technological innovation, including in its neighboring CEE countries.

27. CEE-Countries in General (Poland, Hungary, Czech Republic and Slovakia): None of these countries have a genuine national energy market due to their small size, and they are unable to achieve sustainable energy security on their own. The challenges for the future of coal, and in particular those arising from the introduction of clean technologies, including CCS projects, cannot be solved exclusively or primarily at the national level. Instead, it is necessary to consider stronger cooperation on a regional (EU-10) or sub-regional (Central East Europe) level, and to utilize available and new emerging technologies and develop joint strategies for expensive projects.

4. ANNEX

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